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International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H04R 3/06, 19/04

A1

(11) International Publication Number: WO 94/23547

(43) International Publication Date: 13 October 1994 (13.10.94)

(21) International Application Number: PCT/DK94/00142

(22) International Filing Date: 6 April 1994 (06.04.94)

(30) Priority Data:
0415/93 7 April 1993 (07.04.93) DK

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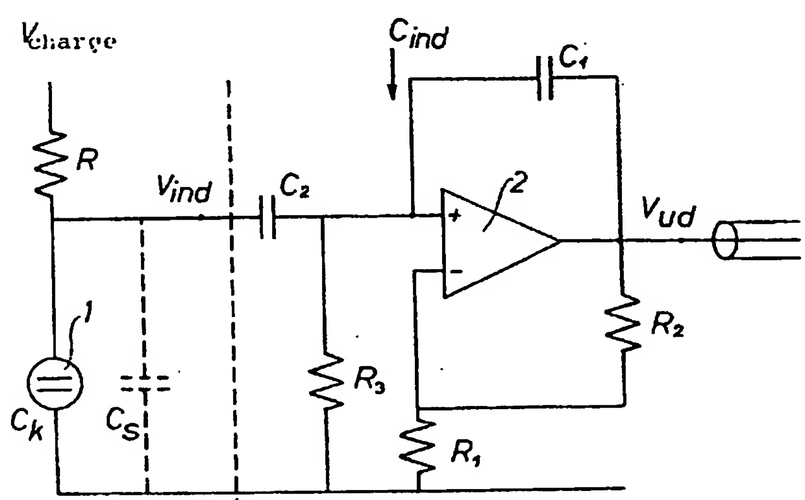
(81) Designated States: AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, GE, HU, JP, KG, KP, KR, KZ, LK, LU, LV, MD, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SI, SK, TJ, TT, UA, US, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: A METHOD AND A COUPLING FOR REDUCING THE HARMONIC DISTORTION OF A CAPACITIVE TRANSDUCER

(57) Abstract

A method and a coupling for reducing the harmonic distortion of a capacity transducer (1), such as a microphone, such as a capacitor microphone, the capacity (C_k) of which is altered in response to a sound pressure on the capacitor electrode (the membrane) by means of a negative capacity. According to the invention the negative capacity is coupled in parallel to the accoustic transducer (1) and dimensioned so as to eliminate the effect of the undesired capacities (C_S) causing the distortion. In this manner the harmonic distortion of the capacity transducer (1) is reduced to a minimum.



$$A = 1 + \frac{R_2}{R_1}$$

$$C_{ind} = -C_1(A-1) = -C_1 \frac{R_2}{R_1}$$

Title: A method and a coupling for reducing the harmonic distortion of a capacitive transducer

Technical Field

The invention relates to a method of reducing the harmonic distortion of a capacitive transducer, such as a capacitor microphone, the capacity of which is altered in response to a sound pressure on the electrode (the membrane) of the capacitor microphone, said distortion originating from undesired capacities in the transducer, by means of a negative capacity connected to said transducer. The invention relates furthermore to a coupling for carrying out the method.

Background Art

Capacitor microphones present a very high fidelity and are therefore used in almost all professional systems. They are also used in consumer devices and in personal equipment, such as tape recorders and hearing aids.

The high fidelity is of particular importance in measuring systems and other professional systems, where large dynamic ranges free of noise and distortion are the object.

The dynamic range is limited at low sound levels by the noise of the microphone and by the noise of an amplifier placed after the microphone.

At high sound levels, the limit is in practise set by a non-linear distortion uniformly increasing with the signal level and being caused by the microphone; or by an abrupt cutting of the microphone signal caused by the signal level in the succeeding amplifier.

It is known that an electric capacity in parallel to the set noise of the microphone increases the distortion of the microphone, cf. for instance Brüel & Kjær Technical Review No. 4, 1979, page 18.

As capacitor microphones in practise present very high electric impedances compared to the succeeding connecting cables and amplifiers, it is usually necessary to place an amplifier close to the microphone. The amplifier provides the necessary impedance matching and has typically a voltage gain of slightly below 1. The amplifier is optimized to drive long cables and presents such a high input impedance that the microphone is only insignificantly loaded. The input impedance is typically between 10 and 50 times 10^9 Ω, and the input capacity is typically between 0.3 and 1 pF. This low input capacity can for instance be provided by means of a preamplifier in form of a field effect transistor coupled as source follower.

A screen around the input terminal of the preamplifier can be connected to the output of the preamplifier, the signal voltage therein then being in phase with the input voltage and only being slightly lower than said voltage. As a result, the resulting input capacity is reduced in the preamplifier because a stronger current in the capacity between the input terminal and the frame has then been replaced by a weaker current in the capacity between the input terminal and said screen.

Thus modern preamplifiers only load the microphones insignificantly.

Measuring microphones are cylindrical and often characterised by their external diameter. The most conventional sizes are 1", 1/2", 1/3", and 1/8" with capacities of 60 pF, 20 pF, 6.5 pF, and 23.5 pF, respectively. Some of the capacity is formed by the active signal-generating capacity between the membrane and the back electrode, whereas another portion of the capacity is passive and originates from the mounting of said back

electrode in the microphone housing and from the output terminals of the microphone capsule.

The passive portion C_s of the capacity, cf. Fig. 2, is almost the same for all microphone sizes, viz. 2 to 3 pF. The ratio of the passive to the active capacity is typically 4% for the largest types of microphone and 200% for the smallest types of microphones.

It is known from German Auslegeschrift No. 2,928,203 that the passive portion of the capacity may cause harmonic distortion. Attempts have been made at solving this problem by means of two capacitors of the same value and coupled in series, where one capacitor is positive and the other capacitor is negative, said capacities being coupled in series with the microphone. This coupling is encumbered with the drawback that the microphone is loaded to a disadvantageous degree, which increases possible distortions.

Brief Description of the Invention

The object of the invention is to provide a method of reducing the harmonic distortion of a capacity transducer by optimizing the load thereof.

A method of the above type is according to the invention characterised by the negative capacity being coupled in parallel to the transducer and being dimensioned such that it corresponds substantially to the sum of the undesired capacities. The resulting optimizing is performed by neutralizing the effect of the dissipation capacity of the microphone and thereby minimizing the harmonic distortion.

The invention relates furthermore to a coupling for carrying out the method according to the invention for reducing the harmonic distortion of a capacity transducer, such as a capacitor microphone, the capacity

of which is altered in response to a sound pressure on the electrode (the membrane) of the capacitor microphone, said distortion originating from undesired capacities in the transducer, by means of a negative capacity connected to said transducer. The coupling is according to the invention characterised by the negative capacity being coupled in parallel to the transducer and substantially corresponding to the sum of the undesired capacities. The resulting capacitive transducer presents a lower distortion than previously known.

When the capacitive transducer is connected to a preamplifier, the negative capacity may according to the invention be provided by the preamplifier with a positive capacitive feedback implying that the preamplifier has a negative input capacity. In this manner the available preamplifier is utilized, and substantially no more than a single additional component is required for establishing the negative capacity. The negative input capacity of the preamplifier is preferably 2 to 3 pF.

Finally according to the invention, the negative input capacity of the preamplifier may be variable, whereby the input capacity can be set until the harmonic distortion has a minimum value.

Brief Description of the Drawings

The invention is explained in greater detail below with reference to the accompanying drawings, in which

Fig. 1 illustrates a capacitive transducer with a coupling according to the invention, and

Fig. 2 illustrates the imperfections of the capacitor microphone.

Best Mode for Carrying Out the Invention

The capacitive transducer of Fig. 1 can for instance be formed by a microphone 1, such as a capacitor microphone, charged from for instance a DC source V_{charge} through a resistance R. When it is a question of a capacitor with two parallel plates and a constant charge, the voltage increases proportional to the distance between the plates when said plates are removed from one another, and when said distance is reduced the voltage drops proportional thereto. This is known and applies to a capacitor without rim effects and without a load. This proportionality is the ideal for a capacitor microphone. The ideal image is, however, disturbed both by unavoidable stray capacities and by the membrane not being moved to an equal extent across the entire surface, cf. Fig. 2. This is equivalent to the situation where the most oscillating portion, i.e. the central portion, is loaded by the least oscillating portion, i.e. the rim portion which is a passive parallel capacity C_s. As a result, there is no proportionality between oscillations (sound pressure) and voltage, which means that a distortion occurs. The ideal ratio corresponds to

$$Q = C_k \cdot V$$

$$C_k = \frac{k}{d} \text{ and}$$

$$V = \frac{Q}{C_k} = \frac{Q}{k} . d$$

where

Q is the charge on the capacitor, C_k is the capacity of the capacitor, d is the distance between the capacitor plates, and k is a constant.

According to the invention the above problem has been solved by a negative capacity being coupled in parallel to the microphone. This negative capacity serves to eliminate the effect of undesired capacities

and corresponds substantially to the sum thereof. The negative capacity can be provided by means of a succeeding preamplifier 2 providing an impedance matching to a connecting cable. The preamplifier 2 is coupled such that it has a negative input capacity C_{ind}. The negative input capacity C_{ind} is provided by means of a positive capacitive feedback, such as by a capacity C_1 being coupled between the output of the preamplifier 2 and the positive input terminal.

The negative input capacity is thereby $C_{ind} = -C_1 (A-1)$, where A is the amplification before the feedback is provided through the capacity C_1, and C_1 is the capacity coupled between the input connected to the capacitor microphone 1 and the output being in phase therewith. The capacity C_1 can be variable in such a manner that an optimum value can be obtained in response to the microphone on which the coupling is used. The sum of the passive parallel capacity and the input capacity must not become negative because the circuit may otherwise oscillate. Usually, the positive capacitive feedback must be so strong that the preamplifier corresponds to a negative input capacity C_{ind} of a few pF, preferably 2 to 3 pF.

C_1 can have a value of 25 pF if the ratio of R_1 to R_2 is 10. R_2 can have a value of 5 KΩ, and R_1 can have a value of 50 KΩ. Then C_{ind} is -25 pF $(1 + 5/50 - 1) = -2.5$ pF.

C_1 is for instance set by a pure sinusoidal sound signal of for instance 1000 Hz being fed to the microphone 1. Then the harmonic distortion or the distortion is measured and C_1 is set until said harmonic distortion or distortion assumes a minimum. In connection with a typical capacitor microphone, the harmonic distortion should be reduced by approximately 10 to 20 dB. The improvement depends, however, on the size of the capacitor microphone.

In order to determine the DC level on the input of the preamplifier and in order to isolate said level from a possible polarisation voltage V_{charge}, a complex comprising a capacity C_2 and a resistance R_3 is in front of the preamplifier 2. The capacity C_2 is situated in the current path from the microphone 1 to the preamplifier 2, whereas the resistance R_3 is coupled between the connection of the capacity to the preamplifier 2 and the frame. In this manner the DC level is determined on the input to frame, C_2 is for instance 100 times greater than C_k. The resistance R_3 must be very high as it together with C_k it determines the lower limit frequency.

The principle can be used in connection with pressure and pressure gradient microphones. It can, however, also be used in connection with electrete microphones.

Claims.

1. A method of reducing the harmonic distortion of a capacitive transducer (1), such as a capacitor microphone, the capacity of which is altered in response to a sound pressure on the electrode (the membrane) of the capacitor microphone, said distortion originating from undesired capacities (C_S) in the transducer (1), by means of a negative capacity connected to said transducer (1), characterised by the negative capacity (C_{ind}) being coupled in parallel to the transducer (1) and being dimensioned such that it corresponds substantially to the sum of the undesired capacities (C_S).

2. A method as claimed in claim 1 where a preamplifier is connected to the capacitive transducer (1), characterised by the negative capacity being provided by the preamplifier (2) with a capacitive feedback implying that the preamplifier (2) has a negative input capacity (C_{ind}).

3. A method as claimed in claim 2, characterised by the capacitive feedback being a positive feedback.

4. A method as claimed in claim 2 or 3, characterised by the preamplifier coupling being dimensioned to a negative input capacity (C_{ind}) of 2 to 3 pF.

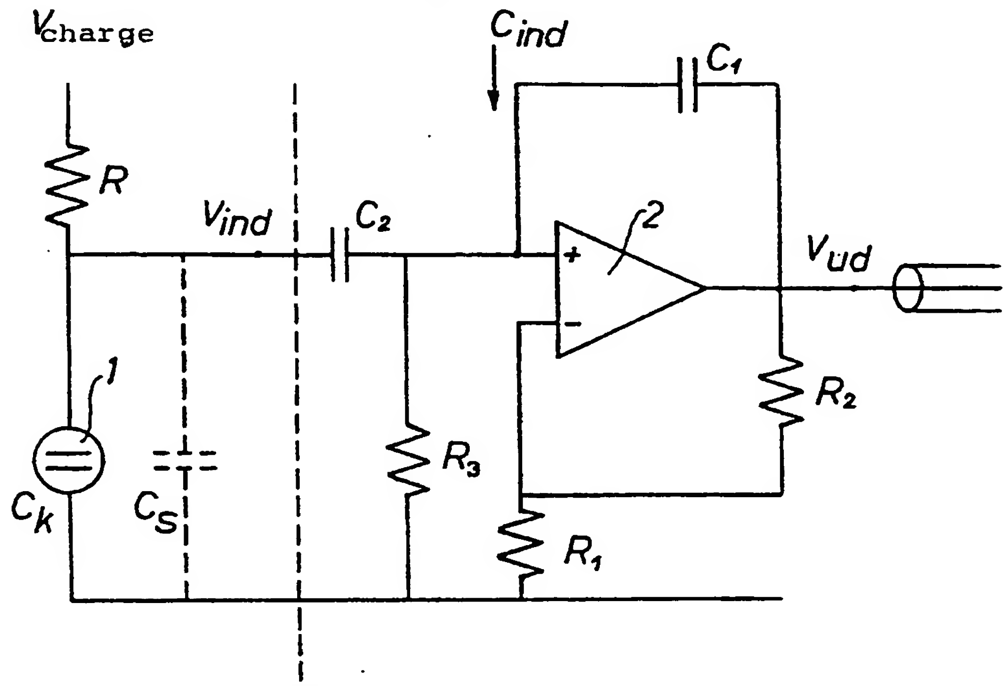
5. A coupling for carrying out the method as claimed in claims 1 to 4 for reducing the harmonic distortion of a capacity transducer (1), such as a capacitor microphone, the capacity of which is altered in response to a sound pressure on the electrode (the membrane) of the capacitor microphone, said distortion originating from undesired capacities (C_S) in the transducer (1), by means of a negative capacity (C_{ind}) connected to said transducer (1), characterised by the negative capacity

(C_{ind}) being coupled in parallel to the transducer and substantially corresponding to the sum of the undesired capacities (C_S).

6. A coupling as claimed in claim 5 and connected to a preamplifier (2), characterised by the negative capacity being provided by the preamplifier (2) with a positive capacitive feedback implying that the preamplifier (2) has a negative input capacity (C_{ind}).

7. A coupling as claimed in claim 5 or 6, characterised by the negative input capacity (C_{ind}) of the preamplifier (2) being 2 to 3 pF.

8. A coupling as claimed in claim 5 or 6, characterised by the negative input capacity (C_{ind}) of the preamplifier (2) being variable.



$$A = 1 + \frac{R_2}{R_1}$$

$$C_{ind} = -C_1(A-1) = -C_1 \frac{R_2}{R_1}$$

Fig. 1

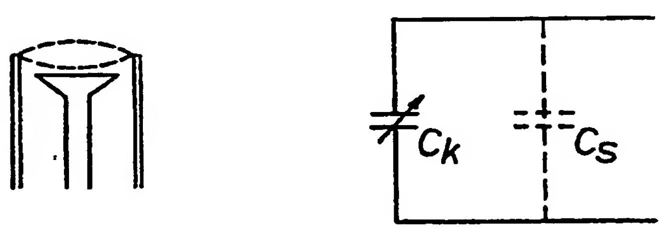


Fig. 2